



Citation analysis and bibliometric approach for ant colony optimization from 1996 to 2010

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ARTICLE INFO

Keywords:

Citation analysis
Bibliometric analysis
Ant colony optimization (ACO)
Bradford Law
Lotka's Law

ABSTRACT

To build awareness of the development of ant colony optimization (ACO), this study clarifies the citation and bibliometric analysis of research publications of ACO during 1996–2010. This study analysed 12,960 citations from a total of 1372 articles dealing with ACO published in 517 journals based on the databases of SCIE, SSCI and AH&CI, retrieved via the Web of Science. Bradford Law and Lotka's Law, respectively, examined the distribution of journal articles and author productivity. Furthermore, this study determines the citation impact of ACO using parameters such as extent of citation received in terms of number of citations per study, distribution of citations over time, distribution of citations among domains, citation of authors, citation of institutions, highly cited papers and citing journals and impact factor of 12,960 citations. This study can help researchers to better understand the history, current status and trends of ACO in the advanced study of it.

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1. Introduction

Ant colony optimization (ACO) is an increasingly important issue in management and optimization to solve difficult and complex real-world problems. Research and development ACO has grown rapidly during the past decade. ACO is a stochastic approach that has been successfully applied to solve different challenging optimization problems, such as traveling salesman problems, quadratic assignment problems, resource-constrained project scheduling problems, permutation flowshop scheduling problems, and vehicle routing problems (Abdallah, Emara, Dorrah, & Bahgat, 2009; Blum & Roli, 2003; Bullnheimer, Hartl, & Strauss, 1999; Costa & Hertz, 1997; Deng & Lin, 2011; Dorigo, Birattari, & Stutzle, 2006; Dorigo & Blum, 2005; Dorigo, Di Caro, & Gambardella, 1999; Dorigo & Gambardella, 1997; Dorigo, Maniezzo, & Coloni, 1996; Gambardella, Taillard, & Dorigo, 1999; Gutjahr, 2000; Maniezzo & Coloni, 1999; Merkle, Middendorf, & Schmeck, 2002; Rajendran & Ziegler, 2004; Stutzle & Hoos, 2000). Accordingly, the ACO literature has also grown rapidly, and thus this study investigates the characteristics of the ACO literature during Jan. 1996 to Dec. 2010 using bibliometric and citation analysis. The specific analysis technique applied here applies bibliography counting to analyze and quantify the growth of the literature on a subject using various laws (Mishra, Panda, & Goswami, 2010; Shiau, 2011; Takeda & Kajikawa, 2009; Tsay, Jou, & Ma, 2000).

Tracing the productometric analysis of ACO publications requires performing citation analysis, which is necessary to judge the quality and impact of ACO papers and their global recognition. Citation reveals the links between pairs of documents, the one, which cites and the other, which is cited. Citation expresses the importance of the material cited, as authors frequently refer to previous material to support, illustrate, or collaborate on specific points. Citation analysis is an important tool in quantitative studies of science and technology. The quality of specific publications can be assessed based on the number of citations in the literature. The use of citation analysis in research on science history is based on a literary model of the scientific process.

The ISI database currently contains records for over 23 million value adding patent records in Chem/Biochem, Engineering, Electronics, going back to 1966 and covering over 22,000 journals. Generally, each record in the ISI database contains an English-language title, descriptive abstract, document type, and full information on cited references and number of citations. The bibliographic information includes the journal or other publication title, author name and affiliation, language of the original document, etc. Indexed document types include books and monographs, conferences, symposia, meetings, journal articles, reports, theses and dissertations.

This study used the search command to retrieve the phrases "Ant system", "Ant algorithm", "Ant colony system", "Ant colony optimization", "Ant colony algorithm", "Ant-based algorithm" or "Ant colony algorithms" from the descriptor field of the ISI database. The main study objective is to clarify the presence of ACO in published citations during 1996–2010 indexed in SCIE, SSCI

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and AH&CI retrieved using the Web of Science. This study has the following specific objectives:

- (1) Explore the growth of the ACO literature.
- (2) Identify citation growth of the ACO literature.
- (3) Determine the time lag between paper publication and first citation.
- (4) Clarify the domain wise distribution of citations.
- (5) Determine a core of primary journals in which the literature on ACO in most heavily represented.
- (6) Examine the distribution of citations among journals.
- (7) Identify highly cited papers and track their citation life cycle.
- (8) Reveal the distribution of the citing journals according to their impact factors.
- (9) Identify the major contributing countries that publish the largest numbers of ACO articles and clarify the distribution of citing papers based on country of publication.
- (10) Find the productivity distribution of authors and their institutions on this subject.
- (11) Determine Cited Authorship Productivity and Lotka's Law.
- (12) Plot the Bradford-Zipf graph.

2. Growth in the published ACO literature

The first paper published on ACO to appear in the ISI database dates to 1996. This study finds that the database contains 1372 journal articles dealing with ACO during 1996–2010. Table 1 lists the number of studies published each year. The table clearly indicates that before 2002, database contained just 36 items dealing with ACO literature. This shows that the collection of ACO papers may not be comprehensive during the initial stage in ISI database. The ISI database indicates that 2003 was the most significant year for the publication of literature. The ISI database contains 57 items dealing with ACO during that year. The article number peaked in 2009, when 250 articles were published. The literature published steadily increased from 2002 to 2010. Fig. 1 plots the annual numbers of published studies on ACO and clearly reveals that the sharpest increase occurred in 2009. Based on the figure, this study predicts that ACO will continue to rapidly grow. Fig. 1 also shows the cumulative growth of the ACO literature based on the ISI. Once again, the ISI database reveals growth in published works on ACO from 1999. Following 2003, the literature grows approximately linearly, exhibiting growth of about 50 items annually.

During 1996–2010, the ACO papers received 12,960 citations. The annual average number of citations was 864, and the average citations per article were 9.43. The number of citations peaked in 2010 at 2929 and continuous growth of citations was found

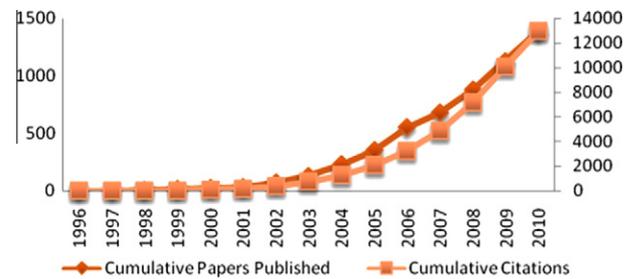


Fig. 1. Cumulative growth of ACO literature & citation trends during 1996–2010.

throughout 1996–2010. The numbers of papers published and the citation rate peaked during 2009 as an inflow of earlier papers continued to receive citations. Table 1 shows the growth in the number of citations of the ACO literature over the 15 year period. Fig. 1 presents the growth and trends of citations of ACO publications per year, and clarifies the information in Table 1.

3. Citation frequency of ACO publications during 1996–2010

The development of any scientific and research subject depends heavily on its research output and intellectual publications. However, such outputs become redundant and profitless if scientists do not refer to them. If the citation likelihood is the same for every article, then the citation frequency should increase with the number of articles a journal publishes (Mishra et al., 2010). The data mostly supports this, although numerous articles are never cited. Considering its importance in significance, citation frequency of ACO publications was identified and listed in Table 2.

Eight-hundred and sixty-two of the 1372 papers were cited, while the remaining 500 and 10 papers were not. Of 1372 papers, one paper published in 1996 received 1902 citations in Computer Science and Artificial Intelligence, followed by 702 citations in 1999 in Computer Science, Theory and Methods, and 460 citations during 2000 in the same place. This data clearly reflects that the research on Computer Science conducted by ACO received global recognition.

4. Bradford Law and the journal literature

As discussed previously, the journal article is the single most widespread form of publication. In total, there are 517 journals published 1355 articles dealing with ACO. Of these, 299 journals published only one article on ACO. To identify a core group of journals containing a high proportion of articles on ACO, the Bradford

Table 1
Annual production of ACO literature and citation frequency of ACO publications.

Publication year	Papers published	% of 1372	Cumulative	Citation received	Cumulative citations
1996	1	0.07	1	0	0
1997	3	0.22	4	3	3
1998	3	0.22	7	14	17
1999	9	0.66	16	24	41
2000	12	0.88	28	72	113
2001	8	0.59	36	85	198
2002	39	2.86	75	206	404
2003	57	4.18	132	331	735
2004	100	7.33	232	549	1284
2005	120	8.80	352	790	2074
2006	198	14.52	550	1171	3245
2007	128	9.38	678	1594	4839
2008	198	14.52	876	2335	7174
2009	250	18.33	1126	2857	10031
2010	246	16.79	1372	2929	12960

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